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21st CENTURY SPACE PROPULSION STUDY ADDENDUM

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Final Report

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FOREWORD

This final report addendum was submitted by the Forward Unlimited, Malibu CA on completion of contract F04611-87-C-0029 with the OLAC, Phillips Laboratory (AFSC) (formerly Astronautics Laboratory), Edwards AFB CA 93523-5000. OLAC PL Project Manager was Dr Frank Mead.

This report has been reviewed and is approved for release and distribution in accordance with the distribution statement on the cover and on the DD Form 1473.

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This addendum to the final report on the contract (AL-TR-90-030, 21st Century Space Propulsion Study, October 1990, AD: A229279) evaluates a number of new space propulsion and sensor concepts. The major topics covered were coherent neutrino scattering and its application to neutrino sensors, the use of tethers for power and propulsion in space, the application of high pressure, high energy density materials, specifically metallic hydrogen, to divert velocity thrusters, and the use of solar sails to provide a non-orbiting space platform for surveillance and space-to-surface missiles. Two technical papers are included as appendices.

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INTRODUCTION AND SUMMARY

The main phase of the effort on this contract was carried out during the period from 30 July 1987 through 30 April 1990. The Final Report[1] for this initial phase was published in October 1990. After the completion of the initial phase of the contract effort, an additional set of tasks was added to the contract effort. The work on this phase started on 25 September 1990 and was completed on 15 January 1991. This addendum to the Final Report covers that period.

There were four topics to be studied during this add-on effort. The objective was to see if any new approaches to space power, propulsion, or sensors could be found, that had general application to the interests of the Strategic Defense Initiative Office, who funded the additional effort. The topics to be looked at were tethers, solar sails, neutrino sensors, and high energy density materials (HEDM). These topics are covered separately in the following sections.

Enough progress was made in each of the four areas that technical papers were prepared for eventual publication in professional journals. Two of the papers, on using tethers and high pressure HEDM fuels for propulsion, have been submitted to the 27th Joint Propulsion Conference to be held in Sacramento from 24-26 June 1991, and will be published as AIAA conference papers. The other two, on solar sails and neutrino detection, are included as Appendices A and B.

During the entire contract period, a total of twenty-three professional publications were published or prepared for publication. These are listed in Appendix C.

SOLAR SAIL STATITES

During the initial contract effort, the PI invented a new type of spacecraft, called a statite.[1] Unlike a satellite, the statite does not orbit the Earth. Instead, it hangs motionless in the sky while the Earth rotates beneath it. The statite remains stationary by using light pressure force on a solar sail to exactly counteract the attractive gravitational force of the Earth. A patent[2] application was filed on the concept with the U.S. Patent Office. The patent has gone through the first office action and some of the initial claims were accepted, so it is now certain that a patent will be issued. The only question remaining is how broad the final claims will be.

In the discussion of statites in the initial Final Report[1], it is pointed out that since a statite is not orbiting, anything dropped from it does not stay in orbit, but falls straight down. A statite carrying a load of "intelligent crowbars" would be a unique weapon system that could surgically take out individual targets by direct hit-to-kill impact from a terminally-guided atmospheric penetrator with minimal ancillary damage. An estimate was made of the drop time for the projectile. That estimate, found on page 10 of the initial Final Report, was later found to be erroneous. A more detailed analysis of the concept was carried out. This analysis can be found as Appendix A - "Surgical Strikes from Space Using Solar Sail Statites".

The paper in Appendix A describes a technique for building a space weapons platform that hovers over the dark side of the Earth without orbiting. The hovering distance attainable will depend upon the state of solar sail technology, and ranges from 10 to 100 Earth radii. An atmospheric penetrator dropped from a space platform at these altitudes will reach the Earth in times ranging from a few hours to a few days, arriving at the upper atmosphere with essentially escape velocity speed (11 km/s). The projectile would pass through the 150 km of atmosphere in 15 seconds, striking the surface with an energy of 60 MJ per kilogram (a kinetic energy that is 15 times the chemical energy of an equivalent mass of high explosive), making the projectile an effective hit-to-kill weapon without the use of explosives. Small amounts of divert velocity not exceeding 0.5 km/s will suffice to allow the projectile to reach practically any point on the dark hemisphere of the Earth.

Used in limited warfare, a projectile dropped from a statite could reach a target anywhere on the globe in a day without risking US manpower or assets, and destroy that target while causing minimum ancillary damage. It would be an ideal weapon for dealing with terrorists, tinpot dictators, and drug runners (by direct hit) and their plantations (by air bursts).

TETHERS

Tethers are long cables in space that are used to couple spacecraft to each other, to other masses, and to force fields in space. The tether coupling allows the transfer of energy and momentum from one object to another, and so are a form of space propulsion.

Geoffrey R. Landis of NASA/Lewis Research Center has invented a novel concept for using tethers for propulsion near the Earth.[3] The basic concept is that if two halves of a spacecraft (or a spacecraft and its expended booster) are extended on a long tether, the center-of-mass of the extended system shifts slightly downward and the orbital period decreases. This shift in the center-of-mass occurs because the Earth's gravity force causes an acceleration of GMm/r^2 on the masses that varies as the inverse square of the distance r, while the counteracting centrifugal force due to orbital motion causes an acceleration of $m\Omega^2 r$ that is linear in the distance r. For very long tethers, the two forces no longer exactly cancel at the two ends and there is a residual, second order, force which must be balanced by a shift in the center of mass. When the tether is pulled in again, the center-of-mass of the combined system raises upward. By alternately extending and contracting the tether at proper points in the orbit, the tether can be used to "pump" an initially circular orbit into a highly elliptical orbit. Theoretically, if the initial orbit is circular and at an altitude of greater than one earth radii, then the final orbit can be an escape parabola. The angular momentum of the initial and final orbits are the same, so no angular momentum needs to be supplied. The energy of the escape parabola is much greater than the energy of the initial circular orbit, so energy needs to be supplied, either from an onboard power supply or by collecting externally supplied power. Although it looks like the system is "pulling itself up by its bootstraps", it is not. In effect, the tether is "climbing" out of the Earth's gravity well by coupling to the nonlinearities in the gravitational gradient fields or gravity tides.

This concept was examined once again during the additional effort. Geoffrey Landis was contacted, but outside of having his original NASA Technical Memorandum published in a technical journal, nothing new was found. The recommendations made in the initial final report stand as they are.

A concept for using tethers for transport from low Earth orbit to the lunar surface, that was discussed briefly in a previously published survey paper[4], was expanded into a technical paper[5] that will be presented at the upcoming 27th Joint Propulsion Conference.

HIGH PRESSURE (HP) HEDM THRUSTERS

One of the tasks on the additional effort to the contract was to evaluate high energy density material (HEDM) fuels and assess the value of HEDM to SDIO needs. An extensive amount of literature on HEDM research was carefully read, especially the proceedings of the annual HEDM meetings[6] where the contractors present the latest information on their research. The general conclusion reached is that there will be some new compounds found that have a higher energy density than present chemical fuels, but that improvement will only be a few tens of percent at most. The only hope for an order of magnitude improvement is the possible manufacture of metallic atomic hydrogen, which has an energy content per gram 33 times that of storable chemical fuels, and 9 times that of liquid oxygen/liquid hydrogen fuel. (Specific impulse of 1700 sec, compared to 300 sec for storable fuels and 560 sec for cryogenic fuels.)

Unfortunately, metallic hydrogen has to be produced at very high pressures by squeezing minuscule quantities in a diamond anvil cell. It is almost certain the metallic atomic hydrogen will revert back to normal molecular hydrogen when the pressure is released. To be useful for propulsion, the metallic hydrogen fuel must be kept stored under high pressure. If nature is kind, the storage pressure may not have to be the formation pressure.

It is obvious that the requirement for a high pressure fuel tank will cause a metallic hydrogen fueled rocket to suffer a severe weight handicap compared to a normal chemical rocket. In order to determine how severe the handicap would be, an analysis was carried out which compared high pressure HEDM fuels, such as metallic hydrogen, with standard chemical fuels. A technical paper[7] covering the analysis will be presented at the upcoming 27th Joint Propulsion Conference.

In the paper it is shown that if a high pressure tank can be built with a design tensile yield strength that is greater than the pressure needed to contain a HP-HEDM fuel, and the fuel has an exhaust velocity greater than 15 km/s (I_{sp}>1500 sec), then such a HP-HEDM propulsion system, even with its thick-walled fuel tank and resultant low fuel fraction, can give <u>better</u> performance than standard low pressure chemical fuel propulsion systems, whether they use storable or cryogenic fuels. This was found to be especially true for the case of small divert velocity thrusters used on small vehicles, such as the "Brilliant Pebbles" being studied by the Strategic Defense Initiative Office. The mass fuel fractions needed vary from 29% (fuel tank three times the mass of the fuel) to 9% (fuel tank eleven times the mass of the fuel), depending upon the assumptions for the exhaust velocities of the HP-HEDM fuel and the low pressure chemical fuel.

NEUTRINO DETECTION

One of the tasks on the additional effort to the contract was to continue an evaluation of a potential new method for the sensitive directional detection of neutrinos.

Background

Neutrino detectors have been well known in physics ever since the first detection of a neutrino in 1956. Since the neutrino interacts only weakly with matter, however, these prior neutrino detector designs require tons of interacting material to measure even a few neutrino events a day. Depending upon the design, their directivity is either zero or poor.

Since 1983, Professor Joseph Weber of the University of Maryland and University of California at Irvine has carried out a series of experiments in which he reports that he has observed anomalously high scattering of neutrinos from nearly perfect crystals with high Debye temperatures (see references 1-7 in Appendix B.) This high scattering efficiency allows him to design equipment weighing only a few kilograms that can quickly and easily detect neutrinos with high sensitivity and high directivity.

I will call the experimentally observed anomalous scattering effect, "The Weber Effect", since it is an observed experimental effect that exists independent of theories. Weber has also developed a theory to explain his experimental results. I will call his theory "The Weber Scattering Center Coherence Theory". It is important to recognize that "The Weber Effect" is separate from "The Weber Scattering Center Coherence Theory".

In the early years of the initial effort on the contract, an evaluation was made of the Weber Effect. That evaluation produced a white paper, "The Weber Effect", dated 4 May 1989, which is Appendix C to the October 1990 final report on that primary effort.[1] During the current additional effort, new information about the neutrino experiments was obtained from Weber and others. As a result, the discussion of experimental results in the original white paper was expanded into another white paper, "The Weber Effect Experiments". It is Appendix B to this final report addendum.

Discussion

Most of the scientific community does not believe either in the Weber Scattering Center Coherence Theory or the Weber Effect. Because they don't believe his theory, most scientists dismiss all of his work out of hand and have not attempted to verify his experimental results. To me, the experimental results, because of

their large number and great variety, in terms of different particles, different sources, different detectors, and different setups, have a validity that is independent of theory. The experiments deserve attention, and they have not gotten it.

It would be different if the Weber Effect were some trivial phenomenon of interest to only a small group of specialists. But if the Weber Effect is real, there could be major scientific, military, geopolitical, and economic implications. A sensitive directional detector of neutrinos would make the seas transparent as far as nuclear powered submarines are concerned. Nuclear reactors and most nuclear weapons could not be hidden unless the same concept were used to develop neutrino shields. Neutrino-carried point-to-point communication and direct broadcast signals that pass easily through mountain barriers and even the center of the Earth, not only have obvious military communication uses, but could make obsolete both communication satellite and fiber optic link businesses at the same time.

If the Weber Scattering Center Coherence Theory is found to be correct, and applies to other particles than neutrinos, then improved detectors for many other particles (infrared light, gravitons, axions, cosmic rays) might become available, producing major technological advances in sensors and communication.

The detection apparatus to demonstrate the Weber Effect is neither complicated nor expensive. Although tritium sources are hard to come by, the Sun and commercial nuclear reactors produce lots of neutrinos that have been shown to induce measurable effects in many different versions of Weber's apparatus. These readily available sources should be able to produce similar results in anyone's apparatus. Yet, only one scientist has attempted to replicate the experiments, and has run out of funding after some initial inconclusive results; while another, afraid of being laughed at by the rest of the scientific community, is bootlegging an experiment in secrecy. That is not the way scientific research is supposed to work.

One problem seems to be the Weber theory. Weber has made a mistake by starting nearly all his papers with an extensive discussion of his theory, then following the theoretical discussion with brief descriptions of his experiments and how they prove the theory. By starting out with theory, the reader easily finds fault with the theoretical approach and has a tendency to reject the experiments out of hand when he comes to them. Weber should have kept his theoretical papers separate from his experimental papers.

Weber also made a mistake by not realizing that extraordinary results require extraordinary proof. The descriptions of the experiments in his papers are way too brief, too lacking in detailed discussion, and too dispersed in sometimes hard-to-find

publications. Especially lacking are details of apparatus design, experiment design, control experiment sensitivity levels, number and type of data runs, and data reduction procedures. Each paper has some of this information, but there is not enough to make the results convincing to the typical skeptical scientist. Since Weber did not provide extraordinary proof, no one believes his extraordinary results. That is too bad, since his experiments deserve a better fate.

The purpose of writing Appendix B is to remind everyone that there is not one Weber Effect experiment. There are at least nine different experiments, with different particles, different energies, different sources (with their different spurious emissions), different detector mechanizations (with their different spurious sensitivities), and different crystals. Some of the experiments are full of noise, and some of them have very clean signals. I feel there are too many to ignore. In my opinion, we should forget the theory and concentrate on: First, replicating the experiments until the Weber Effect can be demonstrated at will. Second, varying the parameters such as source energy, crystal type, and crystal dislocation density to understand the sensitivity of the Weber Effect to those parameters (the Weber Theory may be used as a guide to decide which parameters to vary, but other parameters should be studied as well). Third, developing a theory to explain the now well-understood and reproducible Weber Effect.

Recommendations

I recommend that DoD funding agencies stop worrying about the Weber Theory and stop asking the "knowledgeable" (read "technically-prejudiced-by-existing-theories") experts their opinion. They should continue Weber's funding at a reasonable level. They should be more receptive to proposals by other scientists attempting to study the Weber Effect. They should task a DoD or National Laboratory to replicate some of the Weber experiments in an exact manner as possible. Since many forms of the apparatus needed to demonstrate the Weber Effect is not too difficult or expensive to make, the Sun and commercial power reactors can be used as a source of neutrinos, and there are commercial applications to the Weber Effect, the DoD should include the Weber Effect as a topic in the next Small Business Innovation Research (SBIR) solicitation.

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2. Robert L. Forward, "Statite Apparatus and Method of Use", US Patent Application Serial No. 07/294788, filed 9 January 1989.

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6. L.P. Davis and F.J. Wodarczyk, Editors, Proceedings of the High Energy Density Materials Contractors Conference, Long Beach, California, 25-28 February 1990. Air Force Office of Scientific Research, Bolling AFB, DC, 20332-6448.

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APPENDIX A

SURGICAL STRIKES FROM SPACE USING SOLAR SAIL STATITES

Dr. Robert L. Forward

ABSTRACT

A statite is a spacecraft that does not orbit. Instead of using centrifugal force from orbital motion to counteract the gravity pull of the Earth, it uses light pressure from sunlight reflecting off a large solar sail. Since the statite is not orbiting, anything dropped from it falls straight down. A statite carrying terminal-guided atmospheric penetrators ("intelligent crowbars") would be a unique weapon system that could surgically take out individual targets by direct hit-to-kill impact. An intelligent crowbar dropped from a statite at 20 Earth radii would reach the upper atmosphere of Earth in 24 hours. It would be traveling at 11 km/s--nearly escape velocity. The crowbar would pass through the 150 km of atmosphere in 15 seconds, striking the surface with a kinetic energy of 60 MJ per kilogram (15 times the chemical energy in an equivalent mass of high explosive). Used in limited warfare, it could reach a target anywhere on the globe in a day without risking US manpower or assets, and destroy that target while causing minimum ancillary damage. It would be an ideal weapon for dealing with terrorists, tinpot dictators, and drug runners (by direct hit) and their plantations (by air bursts).

SPACE-TO-SURFACE MISSILES

The concept of striking targets on the surface of the Earth with missiles dropped from space platforms was no doubt immediately obvious to any military man as soon as rockets were able to place objects into Earth orbit (the "high ground"). In practice, space-to-surface missiles have not been widely developed for three reasons. First, in order to have a missile fired from an orbiting space platform strike the surface of the Earth, the missile must be slowed from orbital speed, which requires a significant ΔV capability in the first stage (de)booster. This makes the missile larger, and thus more expensive to boost up to the orbiting space base. It turned out to be better to build ground- and sea-based intercontinental surface-to-surface ballistic missiles than space-based space-to-surface missiles. Second, a missile falling from orbit will very likely have a reentry velocity significantly higher than the reentry velocity of a surface-to-surface missile, thus requiring a larger and more massive heat shield. Third, orbiting space launch platforms are "sitting ducks" for any technologically advanced country, while silos and submarines are difficult to attack. Despite these problems, space-to-surface missiles have been seriously considered a number of times over the years, especially as a part of a total ballistic missile defense system. Some obvious examples are the "intelligent crowbars" espoused a number of years ago by Lt. Gen. Graham and the "Brilliant Pebbles" of the present SDIO program.[1]

Now that "peace has broken out" between the major technological powers of the world, the threat of intercontinental ballistic missile attacks has waned. In its place, however, have come new threats. Terrorists sheltered by sympathetic countries, drug dealers operating large drug plantations in "bought" cities and countries, and tinpot dictators, like Saddam Hussein, who have just enough firepower to make it costly, in terms of precious young American lives, to oppose their marauding tactics.

In this paper I propose a new weapon, a space platform that would be able to launch the "intelligent crowbars", "smart rocks", or hardened "Brilliant Pebbles" as space-to-surface missiles--without requiring large deboost rockets. Since the space platform will not be orbiting, there will be no need to deorbit the missiles.

The space platform will use the "statite" concept that I invented[2] and am patenting.[3] Like a hawk hovering motionless in the air over a pasture, waiting to dive down at high speed on some unsuspecting mouse below, the statite will hover motionless in space over the rotating Earth, waiting to drop down one of its space-to-surface missiles at escape velocity speeds on some unsuspecting enemy below.[4,5]

How a statite can hover motionless in space without orbiting is explained in the following sections.

SOLAR SAILS

Solar sails are lightweight sheets of reflective material attached to a spacecraft that use the light pressure force from solar photons to produce propulsive thrust. The light pressure force F_p on a flat solar sail of reflective area A tilted at an angle of θ with respect to the normal to the sun line is:[2]

$$F_p = (2SA/c)\sin^2\theta \quad , \qquad [1]$$

where c=300 Mm/s is the speed of light, and S=1.38 kW/m^2 is the solar light flux constant at the Earth's orbit. The amount of thrust available is not large--about 9 N (40 pound-f) of force per square kilometer of reflective surface. The major advantage of solar sails as a propulsion system, however, is that the spacecraft does not need to carry either an energy source or reaction mass in order to obtain propulsion, and as a result never runs out of fuel.

Over the decades, a good deal of effort has gone into the design of solar sails, and many reports have been written and published,[6-8] although no solar sail has flown to date. It now seems possible that deployable solar sails could be built with dimensions of many kilometers on a side, and deployed masses of less than 1 gram per square meter (1 metric ton per square kilometer).[9] Using these solar sails, it is possible to build a spacecraft that does not orbit, but instead "hovers" motionless in space over the dark side of the rotating Earth.

THE STATITE CONCEPT

The proposed space platform will be a "statite"--a spacecraft that does not orbit.[2] Since the spacecraft does not orbit the Earth, it is not a satellite of the Earth. The definition[10] of the word "satellite" is: "the lesser component of a two body system revolving, together with the primary, around a common center of mass." The generic name of "statite"[2,3] has been coined for this non-revolving spacecraft, since the spacecraft remains essentially static or stationary in space with respect to the common center of mass.

The gravitational attraction of the mass M of the Earth on the mass m of the space platform is given by:

$$F_e = GMm/r^2 \quad , \qquad [2]$$

where $G=6.67\times10^{-11}$ $m^3/kg\cdot s^2$ is the Newtonian gravitational constant and $M=6.0\times10^{24}$ kg.

As shown in Figure 1, to maintain the statite in a fixed equilibrium position, the solar sail on the statite is tilted so that the direction of the resulting light pressure force is radially away from the Earth, opposite to the direction of the Earth's gravitational force. Then the effective area of the sail is adjusted so that the resulting light pressure force F_p given by equation [1] exactly balances the gravitational force F_e given by equation [2]. Since this is an unstable equilibrium condition, continuous control of the sail area and tilt will be required.

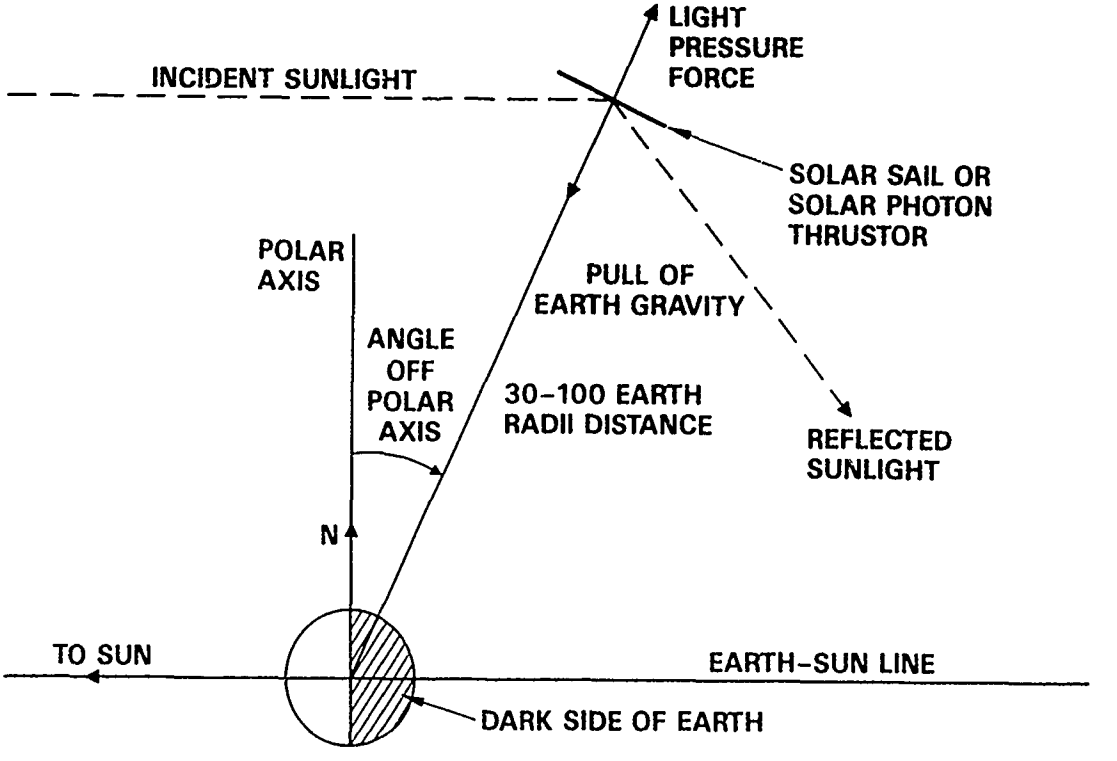

Fig. 1 - The Statite Concept

$$F_e = F_p \quad [3]$$

or

$$GMm/r^2 = (2SA/c)\sin^2\theta \quad . \quad [4]$$

Rearranging equation [4] then gives the equilibrium distance r of the statite from the center of the Earth:

$$r^2 = (GMc/2S)(1/\sin^2\theta)(m/A) \quad . \quad [5]$$

The statites used in this application will probably be placed well over the center of the dark side of the Earth, but out of the Earth's shadow cone. The angle of the solar sail will be nearly broadside to the Sun, so that $\theta \sim 90$ degrees, $\sin\theta \sim 1$, and $1/\sin^2\theta \sim 1$. With this substitution, equation [5] simplifies to:

$$r^2 = (GMc/2S)(m/A) = (4.35 \times 10^{19}\ m^4/kg)\ m/A \quad . \quad [6]$$

Taking the square root of equation [6] and giving distances in terms of Earth radii R=6378 km, and sail mass-to-area ratios in terms of grams per square meter, we obtain a simple relation for the equilibrium distance of:

$$r = 33\ (m/A)^{1/2} \quad . \quad [7]$$

Thus, a statite with a mass-to-area ratio proposed in 1978 for the JPL Halley Comet flyby of 3.3 gm/m^2 (3.3 metric tons per square kilometer) would levitate at a distance of 60 Earth radii while carrying a significant payload of dozens of multi-kilogram-sized projectiles. Second generation sail materials and designs[9] could reach 1.0 gm/m^2 and a levitation distance of 33 Earth radii, while large area futuristic designs[9] could approach mass-to-area ratios of 0.1 gm/m^2, which could levitate at 10 Earth radii distance.

Since a statite is not orbiting, an object dropped from it will not go into orbit around the Earth, but will drop straight down along the radius vector toward the center of the Earth.

PROJECTILE TRAJECTORY

The "drop time", or the time t it takes an initially stationary object to reach the surface of the Earth, and the "impact velocity", or the velocity v at which the object strikes the surface of the Earth, can be obtained by straightforward integration of the Newtonian gravitational force equation. (For simplicity of this preliminary analysis, the effects of the Earth's atmosphere at the end of the trajectory will be ignored.)

The gravitational force F due to the mass M of the Earth acting on the mass m of an object at a distance r from the center of the Earth is given by the well known equation:

$$F = -GMm/r^2 \quad [8]$$

where $G=6.67 \times 10^{-11}\ m^3/kg \cdot s$ and $GM=4.0 \times 10^{14}\ m^3/s^2$. If the object is initially at rest, then the object will drop along the radius vector r toward the Earth with an acceleration $a=d^2r/dt^2=dv/dt$ given by:

$$a = F/m \qquad [9]$$

or

$$dv/dt = -GM/r^2 \quad . \qquad [10]$$

This equation can be solved by multiplying both sides by $2vdt=2(dr/dt)dt=2dr$ and integrating. The resultant equation for the velocity in the radial direction $v=dr/dt$ is:

$$v^2 = (dr/dt)^2 = +2GM/r + C \qquad [11]$$

where C is the constant of integration.

If we use the initial conditions that the object starts out at rest, then when $r=D$, $v=dr/dt=0$, and $C=-2GM/D$. Thus, equation [11] becomes:

$$v^2 = (dr/dt)^2 = 2GM\ (1/r - 1/D) \qquad [12]$$

Taking the negative branch of the square root then gives us the velocity of the object at any point r along its trajectory from the initial point D:

$$v(r,D) = dr/dt = -\ [2GM(1/r - 1/D)]^{1/2} \quad . \qquad [13]$$

The velocity of the object when it reaches the surface of the Earth at one Earth radii, or R=6378 km, is:

$$v(D) = -\ [2GM/R\ (1 - R/D)]^{1/2} \quad . \qquad [14]$$

This equation is shown graphically in Figure 2. As the starting distance D becomes large compared to the radius of the Earth R, we see from equation [14] that the impact velocity of the object approaches the escape velocity from Earth, which is:

$$v(D->\infty) = -\ [2GM/R]^{1/2} = -11.2 \text{ km/s} \quad . \qquad [15]$$

Since practical statite designs will operate at distances greater than 10 Earth radii, for all cases of interest in this study, the impact velocity can be assumed to be 11 km/s.

The energy in an object impacting the surface of the Earth at a velocity of 11 km/s is given by:

$$E = 1/2\ mv^2 = (60\ km^2/s^2)\ m \quad , \qquad [16]$$

or 60 MJ of energy per kilogram of projectile. This kinetic energy is roughly 15 times the chemical energy contained in an equivalent mass of high explosive.

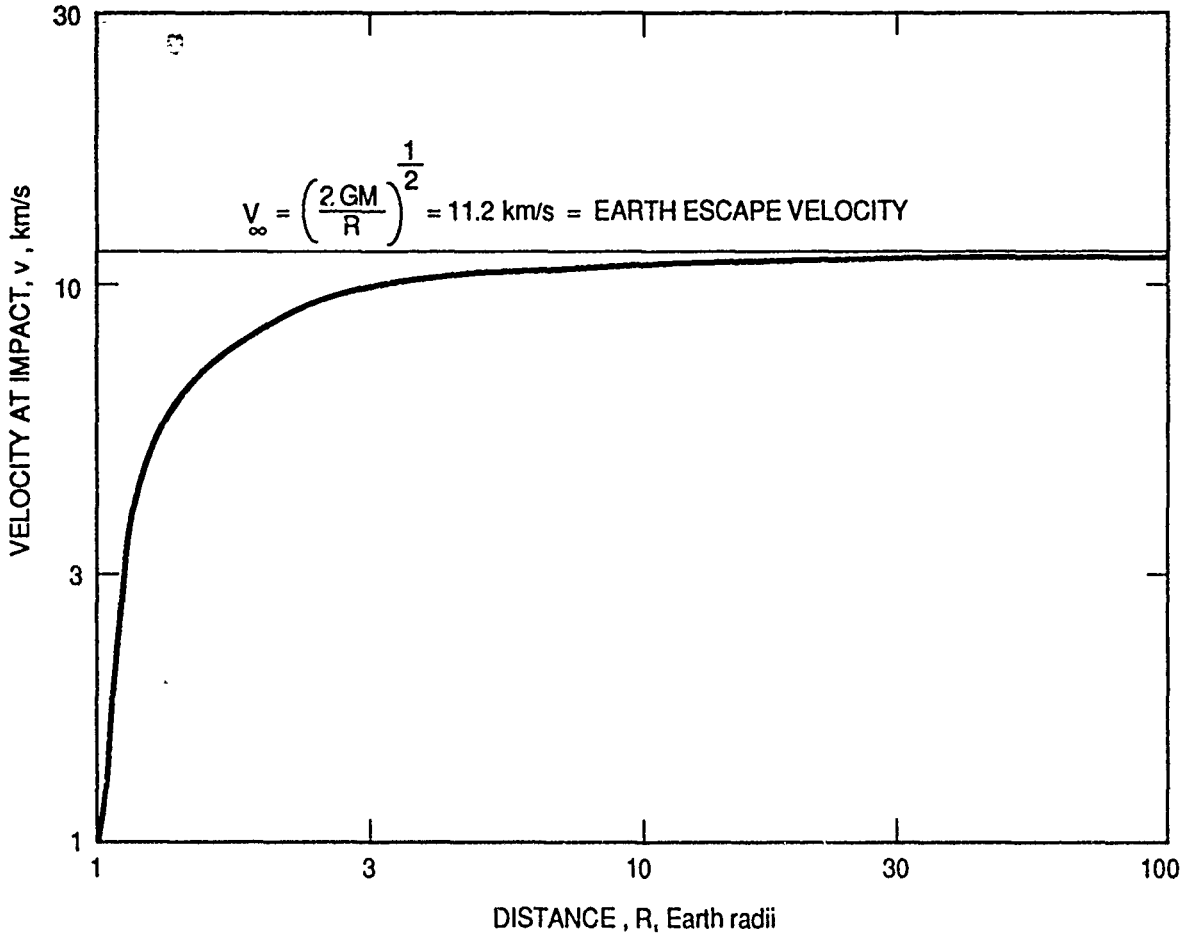

Figure 2 - Impact Velocity vs. Starting Distance

To obtain the drop time to the surface of the Earth, equation [13] can be rearranged into the form:

$$[x/(1-x)]^{1/2}\, dx = -\,[2GM/D^3]^{1/2}\, dt \qquad [17]$$

where x=r/D. This equation can be integrated using standard integral tables[11] to give the drop time from the initial point D to the surface of the Earth at R=6378 km.

$$t = -[D^3/2GM]^{1/2}\{\arctan[(D/R)-1]^{1/2} + [R/D-(R/D)^2]^{1/2}\} \; . \qquad [18]$$

This equation is plotted as the V=0 line in Figure 3.

The asymptotic limit is given by the relatively simple relation:

$$t(D\rightarrow\infty) = \pi/2\; [D^3/2GM]^{1/2} \; . \qquad [19]$$

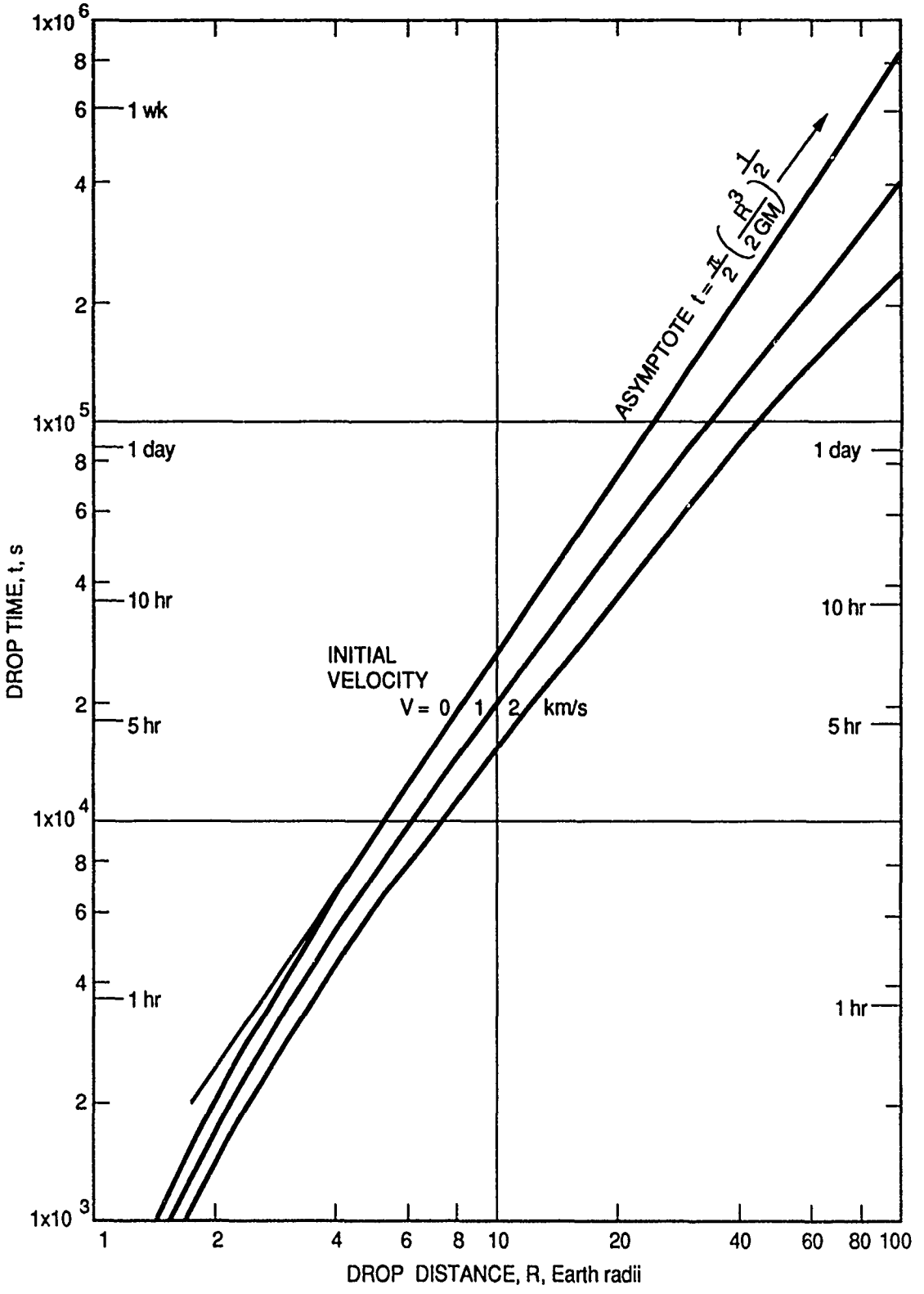

Figure 3 - Drop Time to Earth Surface from Starting Distance

INITIAL VELOCITY AUGMENTATION

The drop time to Earth can be shortened somewhat by giving the space-to-surface projectile an initial velocity V, assumed to be significantly less than the initial velocity needed to deorbit a projectile dropped from an orbiting space platform. By repeating the previous analysis with different initial conditions, it can be shown that the resultant equation for the drop time is:

$$t=-[D^3/2GMB^3]^{1/2}\{\arctan[(D/BR)-1]^{1/2} + [BR/D-(BR/D)^2]^{1/2} - \arctan[(1/B)-1]^{1/2} - [B-B^2]^{1/2}\} \quad . \quad [20]$$

where $B = 1 - V^2D/2GM = 1 -(V/V_{\infty})^2(D/R)$, and V_{∞} = 11.2 km/s

is the escape velocity from Earth. Equation [20] is plotted in Figure 3 for the two cases of V=1 km/s and V=2 km/s. The addition of these amounts of initial velocity decreases the drop time by factors of 1.5 to 2.5, which is a marginal improvement considering the complexity and cost of adding a rocket or catapult booster stage to the system.

DIVERT VELOCITY REQUIREMENTS

The projectile will need some amount of transverse divert velocity capability if it is to be able to strike targets to the north or south of those targets that rotate directly underneath the hovering space platform. In order to be able to strike at any point on the globe, it would be desired to have a footprint of the order of 6378 km radius--equal to the radius of the Earth. The divert velocity requirement $\triangle v$ for a given drop time t is simply:

$$\triangle v = R/t = (6378 \text{ km})/t \quad . \quad [21]$$

For a high performance sail hovering at only 10 Earth radii, the drop time from equation [10] and Figure 3 is t=28,000 seconds, which results in a divert velocity requirement of $\triangle v$=0.23 km/s. Even with an initial velocity of V=2 km/s, which lowers the drop time to only 15,800 seconds, the required divert velocity from 10 Earth radii distance is still only $\triangle v$=0.4 km/s, a small fraction of the initial velocity requirement.

SUMMARY

This paper has described a technique for building a space weapons platform that hovers over the dark side of the Earth without orbiting. The hovering distance attainable will depend upon the state of solar sail technology, and ranges from 10 to 100 Earth radii. An atmospheric penetrator dropped from the space platform will reach the Earth in times ranging from a few hours to a few days, arriving at the upper atmosphere with essentially escape velocity speed (11 km/s). The kinetic energy at these speeds is equivalent to 15 kilograms of high explosive per kilogram of projectile mass, making the projectile an effective hit-to-kill weapon without the use of explosives. Small amounts of divert velocity not exceeding 0.5 km/s will suffice to allow the projectile to reach practically any point on the dark hemisphere of the Earth. Whether projectiles can be built that

can penetrate the atmosphere at such speeds and accurately strike targets on the rotating surface of the Earth is not known. Whether such weapons, with their built-in time delay between launch and strike, would be useful for surgical strikes from space against small targets of accurately known future physical location would depend upon the particular scenario.

ACKNOWLEDGEMENTS

This work was supported by the Phillips Laboratory through Air Force contract F04611-87-C-0029 with Forward Unlimited.

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APPENDIX B

THE WEBER EFFECT EXPERIMENTS

Dr. Robert L. Forward

BACKGROUND

Professor Joseph Weber of the University of Maryland and University of California at Irvine has carried out a series of experiments in which he reports that he has observed anomalously high scattering of neutrinos and photons from nearly perfect crystals with high Debye temperatures.[1-7] I will call the experimentally observed anomalous scattering effect, "The Weber Effect", since it is an observed experimental effect that exists independent of theories. Weber has also developed a theory to explain his experimental results. I will call his theory "The Weber Scattering Center Coherence Theory". It is important to recognize that "The Weber Effect" is separate from "The Weber Scattering Center Coherence Theory". The Weber theory could be wrong, while the Weber Effect could still exist.

Most of the scientific community does not believe either in the Weber Scattering Center Coherence Theory or the Weber Effect. Because they don't believe his theory, most scientists dismiss all of his work out of hand and have not attempted to verify his experimental results. To me, the experimental results, because of their large number and great variety, in terms of different particles, different sources, different detectors, and different setups, have a validity that is independent of theory. The experiments deserve attention, and they have not gotten it.

It would be different if the Weber Effect were some trivial phenomenon of interest to only a small group of specialists. But if the Weber Effect is real, there could be major scientific, military, geopolitical, and economic implications. A sensitive directional detector of neutrinos would make the seas transparent as far as nuclear powered submarines are concerned. Nuclear reactors and most nuclear weapons could not be hidden unless the same concept were used to develop neutrino shields. Neutrino-carried point-to-point communication and direct broadcast signals that pass easily through mountain barriers and even the center of the Earth, could make obsolete both communication satellite and fiber optic link businesses.

If the Weber Scattering Center Coherence Theory is found to be correct, and applies to other particles than neutrinos, then improved detectors for many other particles (infrared light, gravitons, axions, cosmic rays) might become available, producing major technological advances in sensors and communication.

THE WEBER SCATTERING CENTER COHERENCE THEORY

Weber has published in numerous places[1-4,6,7] a theoretical explanation of his experiments with neutrinos scattered off crystals. He attributes his anomalous experimental results to a coherent interaction between the scattering centers in the crystal, which are the quarks in the crystal nuclei. This coherent interaction causes the scattering cross section for neutrinos to increase by the square of the number of scattering centers. The effect becomes large only if the crystal is nearly perfect and has a high stiffness (high Debye temperature). This Weber coherence is due to the interactions of the nuclei with each other through the elastic fields in the crystal and has nothing to do with the "wavelength" of the neutrino. It is essentially the same type of "coherence" between nuclei in a crystal that is used to explain the Mössbauer effect, but in reverse. Many papers have been written proving that Weber's theory is wrong. Weber, of course, does not agree with them.[7] Whether the Weber Theory is correct or not is irrelevant to the thesis of this paper, which is to describe a large number of experiments which could be very important and yet are being ignored by the scientific community.

THE WEBER EFFECT EXPERIMENTS

Most of the experiments demonstrating the Weber Effect have been carried out over the past eight years by Weber himself. Recently, experiments have been done by others in cooperation with Weber. To illustrate the large variety of particle energies, particle types, particle sources, interaction mechanisms, and detector types used, I will enumerate (not in chronological order) the different types of experiment in some detail. Further detail can be obtained from the publications referenced. Some of these different types of experiments have been carried out many times. Weber has estimated the number to be in the "several hundreds".[7]

Exp. 1 - Torsion Balance Detection of Small Tritium Source

The first experiments[2,4] by Weber used the antineutrinos from a 600 Ci (curie) tritium source to create a repulsive force of 4×10^{-7} dynes on a 12.7 gram crystal of sapphire (aluminum oxide) 2.54 cm in diameter (5.1 cm^2 area) and 0.38 cm thick with approximately 1000 dislocations per square centimeter[4], and a Debye temperature of 1000 K.

Tritium has a half-life of 12.3 years and emits a beta particle and an antineutrino with a combined energy of 18.6 keV. It is estimated that the antineutrinos have an average energy of about 12.4 keV, while the beta electrons have an average energy of about 6.2 keV. A 600 Ci source produces 2×10^{13} antineutrinos/s.

The repulsive force on the crystal was measured using a torsion balance made of a tungsten fiber supporting an aluminum disc with the sapphire crystal on one side and a dummy weight of lead on the other. The measured force[2] of 4×10^{-7} dynes corresponded to a neutrino elastic scattering cross section of approximately 1.5 cm^2, which approaches the physical cross section (5.1 cm^2) of the crystal.

Exp. 2 - Torsion Balance Detection of Large Tritium Source

The second experiment[1,4,5] by Weber used a 3000 Ci tritium neutrino source, a torsion balance containing sapphire crystals with diameter of 2.54 cm (area 5.1 cm^2) and a thickness of 0.6 cm, and better controls. The tritium source was in the form of titanium tritide sponge enclosed in a stainless-steel, thin-walled capsule that was 1 cm in diameter and had a wall thickness of 0.8 mm. This wall thickness insured that all beta electrons (maximum energy 18.6 keV) were stopped within the container. Radiation detectors found no significant beta or gamma ray emission from the capsule.

The 3000 Ci source generated about 0.1 W as the result of the beta decay electrons being stopped in the container. Possible thermally induced effects due to this heating were reduced by using a resistively heated dummy capsule with the same size, mass, and heat output as the tritium source capsule. (See Fig. 1).

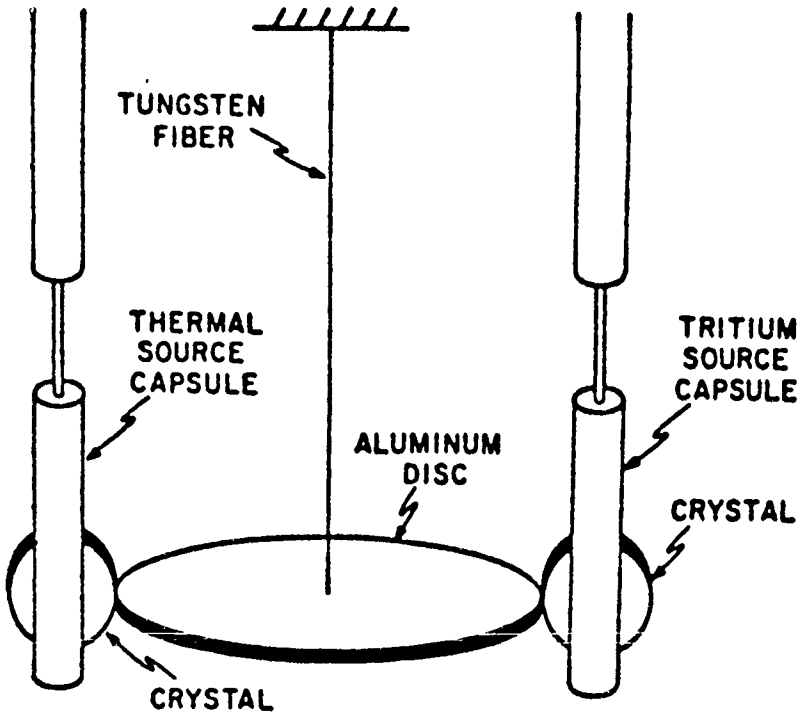

Fig. 1 - Torsion Balance and Source Capsules

The torsion balance was operated in the force feedback mode, in which an electrostatic feedback force maintains the balance at its equilibrium position. The balance was calibrated by replacing the capsules with masses ranging from 8-27 grams that gave a known gravitational attraction. The balance was isolated from the environment by thermal blankets and a vacuum chamber kept at a pressure of 10^{-6} Torr. The vacuum chamber had re-entrant sealed sleeves open to the air, that allowed the long, narrow capsules to be lowered down close to the sapphire target crystals. The capsules were cycled up and down with a period of typically 64 seconds. Details of the experimental procedures and the controls used can be found in refs. 1 and 5.

There were more than 200 separate runs, each at least several hundred cycles. About half employed a 64-second cycling period and about half employed a 32-second cycling period. Two torsion balance discs with different moments of inertia were employed. Linearity, thermal response, magnetic response, and effects of different source strengths and calibration masses were also studied.

This second experiment gave essentially the same results as the first experiment. The neutrino scattering cross-section was tentatively estimated by Weber as 1.06 ± 0.44 cm^2 in ref. 1, and later,with more accurate bias corrections, as 2.05 ± 0.23 cm^2 in ref. 5. Both estimated cross sections again approached the physical cross section (5.1 cm^2) of the crystal.

Exp. 3 - Torsion Balance Detection of LANL Tritium Source

The third experiment is a repeat of Weber's first two experiments, and is being carried out at Los Alamos National Laboratory (LANL) by Dr. Mario D. Grossi, of Smithsonian Astrophysical Laboratory (SAO) and Raytheon Submarine Signal Division, using a differently constructed tritium antineutrino source. The torsion balance detector was supplied by Prof. Weber, the tritium source of antineutrinos was supplied by LANL, and the data acquisition system and rotating table, to rotate the source past the torsion balance, was supplied by Raytheon. The first phase of the work was carried out from August 1988 to January 1989 and is described in a two volume contract report[8] dated 7 September 1989. The second phase of the work started in August 1989 and is still underway at this time. What has been accomplished thus far in this second phase is described in quarterly progress reports (three issued thus far by SAO).[9]

In the first phase, the torsion balance was mounted at a fixed location, close to the edge of the 1 RPM rotating table. On the edge of the table was placed either a 100,000 Ci tritium-filled container (the antineutrino source) or a deuterium filled container (providing an equivalent gravity force source for reference). As the table rotated, the sources were moved by the torsion balance, which responded to the combination of gravity and neutrino forces from the sources.

The experiment consisted of a comparison between the output of the torsion balance, integrated each time for 168 hours (10,080 rotations of the 1 RPM table), first using the deuterium filled container and then using the tritium filled container. There was a difference between the integrated outputs. This difference would be consistent with a repulsive force which is present when the tritium is used. The intensity of this repulsive force was approximately 10^{-11} N (1 microdyne). This repulsive force was an order of magnitude smaller than the attractive gravity force from the 2.6 kg containers, and was compatible with the observations that Weber had seen at the University of Maryland in 1986 with his 3000 Ci source.

The experiment was repeated with a 1/4 inch lead shield wrapped around the 8 inch diameter cylinder that houses the torsion balance. This time, there was no difference greater than random noise between the two sets of data (one for the tritium source and one for the deuterium source). This set of experiments would seem to indicate that the apparatus had the ability to detect a sealed tritium source at a distance, but it was caused by something that can be shielded by a quarter-inch of lead.

Rather than coming to a negative conclusion, however, Grossi considered this only a preliminary result, and emphasized that no conclusions, either positive or negative, should be drawn from these two preliminary sets of data. First, the integrated signals were just barely above the remaining noise (see Figs. 2.3-1, p. 73 and 2.3-3, p. 78 in the contract report[8]) and the runs need to be repeated to be believed. Second, during the second set of runs with the lead shield, the temperature changed in the laboratory, and the period of oscillation of the torsion balance changed significantly between the run with the deuterium sphere and the tritium sphere (see Fig. 2.3-2, p. 77 in the contract report[8]). The data had to be "stretched" in time in order to compare the curves, raising many questions about the validity of the negative result.

In the second phase of the measurement campaign, still underway, the experiment instrumentation has been improved substantially. A walk-in enclosure was built to house the torsion balance, its electronics and the rotating table. It is thermally controlled to ± 1 C. Prof. Weber modified the damping on the torsion balance to achieve near-critical damping. Twenty-five mass replicas of the tritium source were built by LANL and mounted all around the rim of the rotating table to reduce the gravitational field variations as the deuterium and tritium sources are rotated past the torsion balance. Full details of the improvements can be found in the SAO Quarterly Report #1 dated December 1989.[9]

With the improved system, LANL and SAO resumed data collection in January 1990. First, the solo container tests[8] of November 1988 were repeated. A single container was placed on the rotating table and rotated by the torsion balance. First the tritium container and then the deuterium container. The output of the torsion balance was integrated over 10,000 rotations of the

table (one week of time) for each container. When they computed the difference in the output of the torsion balance for the two different containers they obtained a differential repulsive force of the order of a microdyne, similar to the outcome of the first tests in November 1988. Now, however, the signal-to-noise ratio was excellent and the shape of the integrated data curve was almost identical to the theoretical expectations (see Fig. 2 in SAO Quarterly Report #2 dated May 1990).[9] The level of the repulsive force observed was in close agreement with what Prof. Weber had observed in his tests conducted in 1987 at the University of Maryland.

Next, LANL and SAO added the 25 mass replicas to the table top and the runs were repeated with the tritium container and the neutrino container. These tests failed to provide a differential force of enhanced intensity above the gravity gradient background. As can be seen in Fig. 4 of SAO Quarterly Report #2 and in Fig. 7 of Quarterly Report #3 dated February 1991, the difference in the tritium run and the deuterium run produced just noise. The experimenters are not yet ready, however, to conclude that this negative result proves that the Weber Effect does not exist. During the experiment, there were problems with the functioning of the torsion balance. There were irregular occurrences of linear pendulum swings in the torsion balance that had a period closely equal to the period of rotation of the table. Although this mode of oscillation can be easily taken out of the data, there is concern that the torsional sensitivity of the balance may be decreased during these swinging oscillations. LANL and SAO are now trying to identify the origin of the problem and eliminate it.

The plans for the future activity at LANL is to repeat the tests with the 25 mass replicas once the torsion balance problem has been corrected. Then, the plan calls for the repetition of the solo container tests. If the differential repulsive force appears again, then the tests will be repeated with the same containers, but with the tritium gas and deuterium gas interchanged between the two containers. If the sign of the differential force does not change, then the differential force is due to the gasses in the containers, and additional support is gained for the existence of the Weber Effect. If the sign changes with the transfer, then the force is container related and probably gravitational in origin. A direct comparison between the mass properties of the two containers is rather difficult. LANL is certain that the two masses are identical within an acceptable measurement error. What is uncertain is the location of the center of mass (they have a complicated structure, with small pipes, valves, turrets, etc.) A relative difference of a few millimeters in the locations of the center of masses could be the cause of the observed differential force.

Should the results of the gas substitution experiments be that the repulsive force is related to the gasses, experiments with shielding will resume, as was done in the first experiments.[8] However, this time, at Weber's request, the shields will be wrapped around the containers, and not around the torsion balance. The susceptibility of the repulsive force to shielding would be a decisive factor in determining whether the repulsive force is caused by antineutrinos.

Major problems remain, however, that may prevent carrying out these planned experiments. First, funds to continue the project are virtually non-existent. LANL used up its project budget about one year ago, while SAO still receives a minimal funding, barely sufficient to cover travel expenses. Second, the laboratory at LANL has been declared health-hazardous because of a high level of tritium contamination and might be closed altogether. Third, the priority assigned to the project by LANL is low, and the test runs are discontinued every time that some other assignment is given to the LANL personnel at the test site.

SAO has tried to motivate the funding agencies and LANL by issuing in December 1990 a Special Technical Report[10] entitled "Consideration in the Application Potential of Low-Energy Neutrino Detectors". The report shows how important a neutrino detector would be to DoD, apart from the scientific significance of the results. This effort has not produced additional funding to date. Notwithstanding, LANL and SAO are determined to complete their assignment and report conclusively whether or not their tests confirm Weber's claim. If things go well, the experiments could be finished by Summer 1991. If the problems remain, and especially if the test facility is closed, the experiments will be postponed indefinitely.

Exp. 4 - Torsion Balance Detection of MeV Reactor Antineutrinos

The fourth experiment[2,5] employed an MeV antineutrino source instead of the keV antineutrino source. The antineutrinos came from a nuclear test reactor at the National Institute of Standards and Technology in Gaithersburg, Maryland, with the experimental apparatus located about 15 m from the 20-MW reactor. The average energy of the reactor neutrinos was estimated by Weber to be 1.6 MeV.

The standard torsion-balance arrangement was used, with a 100 g sapphire crystal on one side and a 100 g lead mass on the other as shown in Fig. 2. A 5 kg "shield" crystal of sapphire was used to "block" the antineutrinos coming from the reactor.

Repulsive force changes of $3.9 \pm 0.4 \times 10^{-5}$ dynes were observed as the shielding crystal was placed between the reactor and the target crystal.[5] The estimated neutrino elastic scattering cross section[2] was approximately 2 cm^2 for the 100 g crystal.

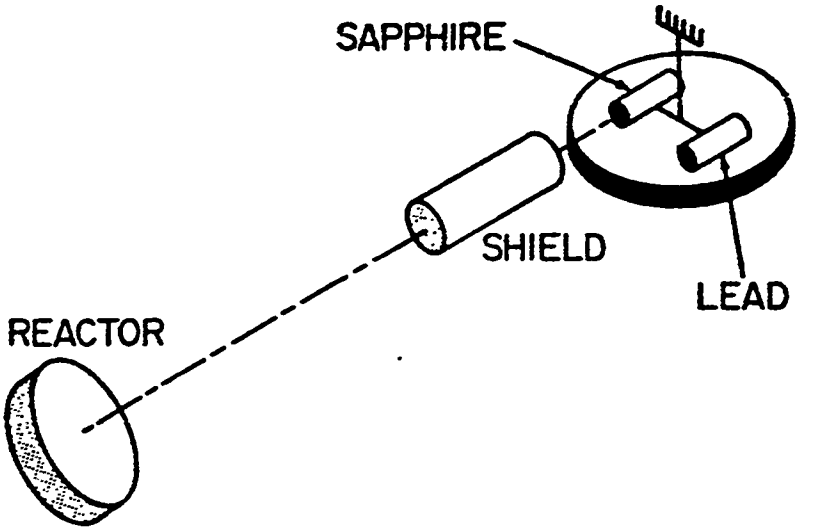

Fig. 2 - Detecting Reactor Antineutrinos

Exp. 5 - Torsion Balance Detection of keV Solar Neutrinos

A fifth experiment[4,5] involved the detection of neutrinos from the Sun. A world-wide effort has been in progress for many years to observe the solar neutrinos using large tanks of tetrachloroethylene or large quantities of gallium. There has arisen a "solar neutrino problem" because the number of neutrinos observed using these standard neutrino detectors has been less than expected on the basis of the standard theory for the thermonuclear reactions in the sun. One possible explanation is that the solar neutrinos are partially converted into muon neutrinos on the way to the earth. The neutrino scattering mechanisms postulated for the Weber Effect have the same cross section for electron, muon, and tau neutrinos. Therefore, Weber Effect experiments should observe the expected number of solar neutrinos.

The torsion balance used in the Weber Effect solar neutrino experiment is shown in Fig. 3. It had a 26 g single crystal of sapphire on one side and several thin sheets of lead on the other.

Details of the equipment and experiment, including data curves, can be found in Weber's 1988 paper.[5] After averaging the output of the torsion balance over a 65 day period, a diurnally varying force of about 4.6×10^{-6} dynes was observed. Using the assumption that most of the solar neutrinos had an energy ranging from 0-430 keV, the solar neutrino flux was estimated to be $5.9 \pm 1.8 \times 10^{10}$ neutrinos per second per square centimeter.[5] This result is consistent with the theoretically expected number of 6×10^{10} neutrinos/s·cm^2.

I have learned that a physicist at another institution is attempting to replicate this Weber Effect solar neutrino experiment using similar equipment. Like me, this physicist believes that experiments showing the Weber Effect have a validity independent of the Weber Theory, and should be replicated if possible. The physicist was not willing, however, to be identified. The person is no doubt afraid he or she will be the object of derision by the rest of the scientific community for even attempting to replicate Weber's experiments.

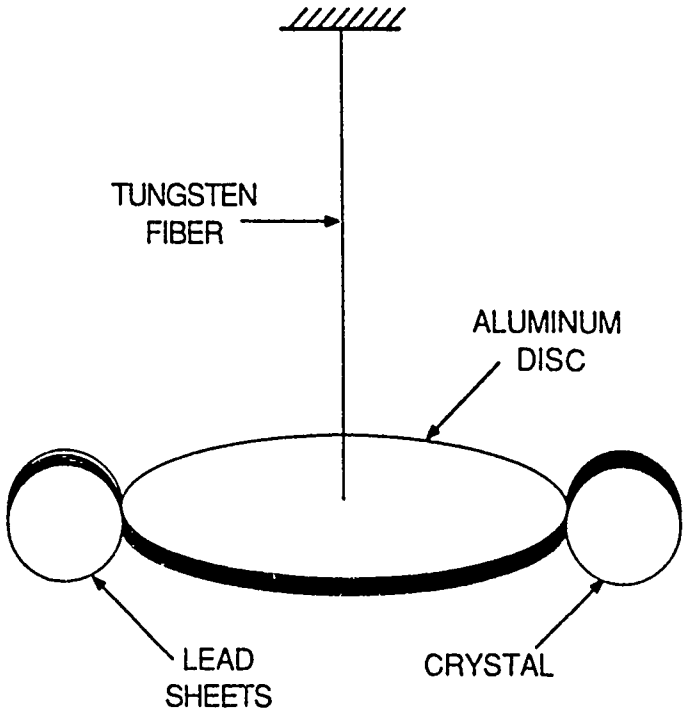

Fig. 3 - Solar Neutrino Detector Apparatus

Exp. 6 - NMR Detected Inelastic-Scattered Reactor Antineutrinos

In the sixth experiment, heating of the nuclear spin system of a stiff crystal was observed when a nearby nuclear reactor was operational.[6,7] Fig. 4 shows a schematic diagram of the experiment. The detector apparatus is a standard Nuclear Magnetic Resonance (NMR) Spectrometer with a high quality sapphire (aluminum oxide) crystal as the sample being studied. The experiment is designed to measure the effective temperature of the nuclear spin system of the ^{27}Al nuclei in the crystal.

The magnetic field was first swept through the NMR peak when the nuclear reactor was off and then again when the reactor was on and generating a flux of about 10^{11} antineutrinos per second per square centimeter. The peak amplitude of the NMR resonance with the reactor on, was roughly half the peak amplitude of the resonance with the reactor off. Weber attributed the decrease in the peak of the NMR resonance to an increase in the spin temperature of the nuclei in the crystal. The increased heating in turn was due to the coherent inelastic scattering of the reactor antineutrinos from the nuclei.

Again, independent of any theoretical explanation, the important result of this experiment was that this apparatus was able to detect the presence of a shielded 20 MW reactor at a distance of 15 meters. Better apparatus could detect similar reactors at even greater distances.

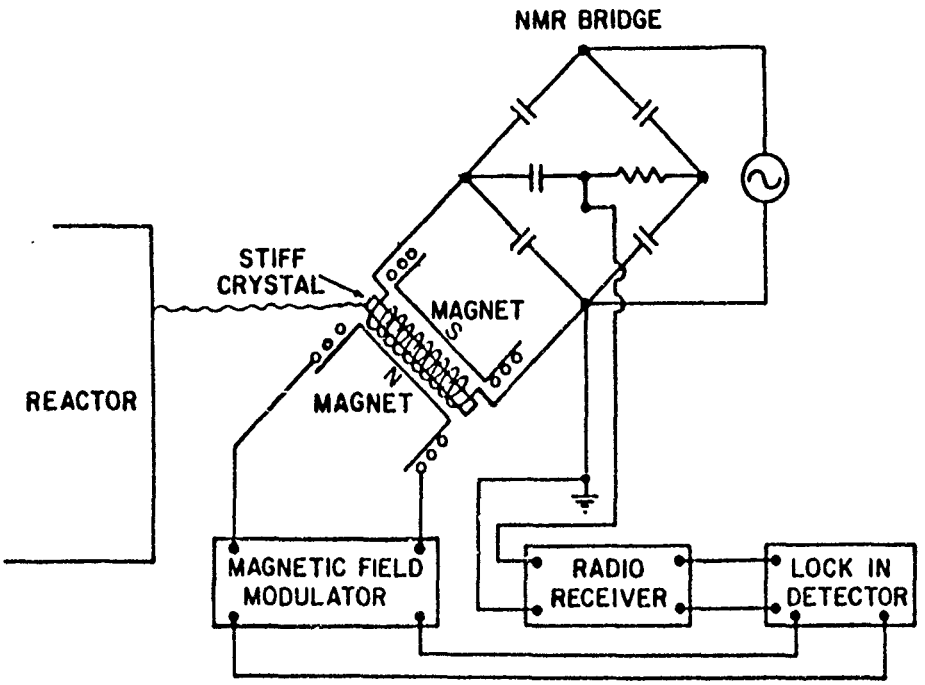

Fig. 4 - NMR Spectrometer Detection of Reactor Antineutrinos

Exp. 7 - NMR Detected Inelastic-Scattered Tritium Antineutrinos

In the seventh experiment, the heating of the nuclear spin system of a stiff crystal was observed at the approach of a tritium source.[6,7] This was interpreted as due to the coherent inelastic scattering of the tritium antineutrinos from the nuclei in the crystal. The detecting apparatus was similar to that shown in Fig. 4, except that the source was a 1000 Ci tritium source producing keV antineutrinos instead of a 20 MW nuclear reactor producing MeV antineutrinos.

The first experiment in the series was carried out with the crystal at a temperature of 4.2 K and immersed in a magnetic field of 5000 G. The magnetic field was slowly swept at a rate of about 160 seconds per sweep, so as to carefully observe the magnetic resonance peak. With the tritium source far from the crystal, the resonant peaks were easily observed and were well above the noise. The peak amplitude remained the same for each sweep.

When the 1000 Ci tritium antineutrino source was brought to a distance of about 1 cm from the crystal, the peak of the resonance line decreased about 20% at each 160 second sweep interval.[6,7] The experiment was repeated at a temperature of 2 K with similar results. Other experiments were carried out at 1000 G magnetic bias field, various radio frequency drive levels and crystal lattice temperatures, and with the sweep turned off and the apparatus tuned to sit on the peak of the NMR resonance line while the tritium source was cycled. The peak of the resonance line was reduced to one-third of its normal value when the tritium source was placed near the sapphire crystal.

With a 5000 G magnetic bias field, no significant effects were observed until the applied magnetic resonance radio frequency fields were large enough to raise the spin system temperature in order to reduce its specific heat. At 1000 G, the spin system specific heat is lower than at 5000 G, so heating effects from the tritium (and reactor) sources could be observed at much lower spin temperatures and low radio frequency fields.

Weber interprets these many and varied experimental results as evidence that the nuclear spin temperature of the Al^{27} nuclei in the sapphire crystal is increased as a result of interaction with the low energy (keV) antineutrinos from the decay of tritium as well as the much higher energy (MeV) antineutrinos from a nuclear reactor.

Exp. 8 - Chopper-Resonator Detection of MeV Reactor Antineutrinos

The eighth experiment involved a new type of detector system.[6] As shown in Fig. 5, the apparatus consisted of two components, a chopper wheel to modulate the flux of neutrinos and a resonant tuning fork detector tuned to the neutrino modulation frequency. The chopper wheel consisted of a metal wheel with six sapphire crystals mounted in holes near the circumference. The crystals were 1.5 in. (3.8 cm) in diameter and 2 in. (5 cm) long. The crystals were supposed to temporarily block the neutrino flux, producing a modulated beam.

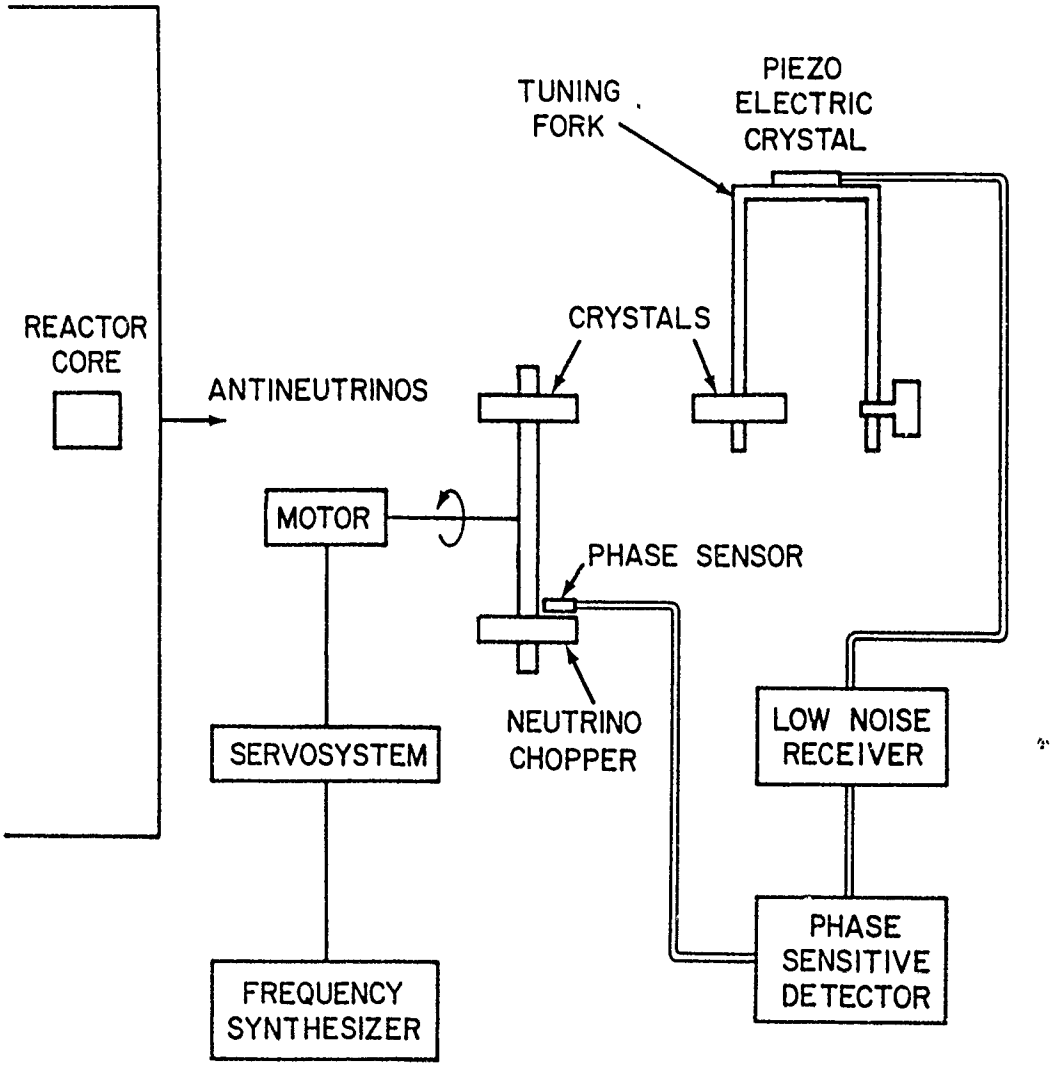

Fig. 5 - Chopper-Resonator Detection of Reactor Antineutrinos

The wheel rotated at 500 RPM, and since there were six crystals on the wheel, the resulting modulation frequency was 50 Hz. The detector proper was a tuning fork with a sapphire crystal 1 in. (2.5 cm) in diameter and 2 in. (5 cm) long on one arm and an aluminum matching weight and a piezoelectric crystal on the other. The resonant frequency of the loaded tuning fork was 50 Hz. It had a Q of 2000 (1/e ringdown time of 13 seconds). The modulated neutrino flux from the chopper exerted 50 Hz forces on the sapphire crystal due to the Weber Effect, and the resonant tuning fork responded by vibrating. The piezoelectric crystal converted the tuning fork vibrations into electrical signals at 50 Hz, and these electrical signals were amplified and detected by a phase sensitive synchronous detector. This detection method was similar to that used in gravitational radiation antennas[1] and resonant gravity gradiometers.[11] It is relatively easy to achieve thermal-noise-limited detection sensitivity in such room temperature resonant mechanical systems.

In November 1988, Weber set up the apparatus at about 15 meters from the 20-MW NIST nuclear reactor at Gaithersburg, Maryland. With him was his DARPA Contract Monitor, Lt. Col. George Lasche. When the chopper wheel was operating properly and the phase on the single-channel lock-in amplifier was properly adjusted, a very strong ("booming") signal was observed from the resonant tuning fork detector. Switching the reactor on and off caused a 40:1 change in the power output of the tuning fork.[6]

When a blocking crystal of sapphire, 4 inches in diameter by 12 inches long, was interposed between the chopper and the detector, the detector signal dropped. When a similar-sized semiconductor-grade silicon crystal was interposed, the signal dropped even more. A sapphire crystal has a Debye temperature of 1000 K, while that of a silicon crystal is only 645 K, but the sapphire crystal had a dislocation density of 100,000 cm^{-2}, while the silicon crystal had relatively few dislocations.

When the blocking crystals were placed in front of the chopper, further from the detector, the signal was smaller, but still significant. When a block of lead (to absorb gamma rays) or polyboron (to absorb neutrons) was imposed, there was no decrease in the signal level. Moving the silicon shield in and out of place with the reactor off also produced no significant effects.[6]

Twenty-seven sets of data (14 pairs, blocked and unblocked, each ten minutes long) were taken. They were analyzed blind by Lt. Col. Lasche using a Student's T test. A definite signal was found, with a probability of error less than 1% when sapphire was used as the blocking crystal, and with negligible probability of error with the much larger signal obtained when the silicon crystal was used to block the neutrinos.

These experiments again showed that the Weber Effect, whatever it is caused by, is real. A chopping wheel and a resonant detector using sapphire crystals as active elements detected the presence of a nuclear reactor at 15 m. The tests with the lead and polyboron showed, that whatever the Weber Effect was caused by, it was probably not due to X-rays or neutrons.

Exp. 9 - Nuclear Spin Detection of Optical Photons

The ninth experiment was especially significant since it showed that there is some sort of coherent interaction possible between perfect crystals and electromagnetic photons, not neutrinos. This experiment was described in a brief contract progress report,[3] where Weber reported an anomalously high absorption of photons by nuclear spins in a cryogenically cooled crystal. Again, the effect was purported to be due to coherent action by the scattering centers. These results have yet to be reported in any detail by Weber in the scientific literature. If they are true, they indicate that anomalously high elastic cross sections are not due to some peculiarity of neutrinos, but can be repeated using easily generated and detected laser photons.

DISCUSSION

It is a canonical belief in physics that a neutrino can pass through thousands of lightyears of lead before scattering; thus these reported experimental cross sections are "impossible," according to conventional neutrino scattering theory. As a result, experimentalists have rejected Weber's results out of hand and no one has attempted to repeat the experiments. Some people have proposed a repeat of the experiments to various funding agencies, but their proposals have been rejected, usually after the funding agency program manager asked the opinion of neutrino detector scientists. One funding agency program manager contacted, is of the opinion that: "Experiments should not be funded unless there is an adequate theoretical underpinning for the proposed work." As an experimentalist, I am of the opinion that theory follows experiment, and that major breakthroughs in theoretical understanding only come when experimental results are obtained that have not been predicted and cannot be understood using present theories.

I think the many experiments done by Weber, especially the experiments involving other people, show that given a strong enough source and a sensitive enough detector, that the Weber Effect exists. The experiments have shown that a properly designed sensor can detect a nuclear reactor or the tritium in a warhead at a short distance. Whether the interaction is caused by neutrinos or not, is only partially relevant. The Weber Effect, whatever it is, allows supposedly shielded nuclear sources to be detected at a distance. This is significant, since improved sensors can detect these sources at interesting distances.

If the Weber Effect turns out to be real, and is found to be due to neutrinos, then it should be possible to develop a series of more and more sensitive neutrino detectors. First generation versions of the neutrino detectors might be able to sense nuclear reactors, including the reactors in nuclear submarines, at many kilometers. More sensitive second generation neutrino detectors might be able to sense nuclear warheads and many radioactive materials at useful distances. Shields of crystals around our military sources of neutrinos could direct the neutrinos away in a

safe direction and prevent our nuclear submarines or warheads from being detected.

Neutrino beams could be formed by collecting and directing the neutrinos from a source such as a nuclear reactor or sealed canisters of radioactive waste. This could be done by surrounding the source with reflecting crystals and then sending the neutrinos out through a collimating hole pointed in the desired direction. The beams could be modulated at MHz to GHz rates with crystals that are acoustically distorted into temporary crystalline imperfection. With these beamed neutrino sources, communication between any two points on the globe becomes possible, even though the path between the two points is blocked by the earth.

If the Weber Effect is found to apply to photons and other particles, then all methods of long range sensing and communication will need to be reevaluated.

CONCLUSIONS

I have listed a series of nine different types of experiments that seems to indicate that the "Weber Effect" is real. The experiment results exist. If the results prove to be reproducible, then they are important to science, national defense, and commerce. Yet, these results are being ignored or rejected by the scientific community, and are receiving low levels of support from the funding agencies. Weber is experiencing great difficulty in finding the funds necessary to keep his present experiments going. Also, as far as I am able to determine, there are no plans extant to replicate the Weber experiments (with the exception of one reluctant-to-be-identified scientist).

The announcement of a possible "fifth force" a few years ago, brought out dozens of experimenters, who were able to find the equipment and funding to carry out dozens of experiments attempting to replicate the original work. After some initial positive results, the scientific community has now pretty well conclusively demonstrated that the "fifth force" doesn't exist. That is the way scientific research should work.

The announcement of possible "cold fusion" produced lots of initial skepticism and scorn from the scientific community, but at least a portion of the scientists were willing and able to find the equipment and funding to replicate the original work. The jury is still out on cold fusion, although hope is fading fast as attempts to replicate the experiments find them difficult to reproduce in a controllable manner. That is the way scientific research should work.

The announcement of what I call "The Weber Effect" has, instead, produced nothing but abusive scorn from the scientific community. This is probably because of the preoccupation by Weber and the scientific community with Weber's theory. The detection apparatus to demonstrate the Weber Effect is neither complicated nor expensive. Although tritium sources are hard to come by, the Sun and nuclear reactors produce lots of neutrinos that have been shown to induce measurable effects in many different versions of Weber's apparatus. These readily available sources should be able

to produce similar results in anyone's apparatus. Yet, only one scientist has attempted to replicate the experiments, and has run out of funding after some initial inconclusive results; while another, afraid of being laughed at by the rest of the scientific community, is bootlegging an experiment in secrecy. That is not the way scientific research is supposed to work.

Something is wrong with the way the scientific community is conducting its research. It should be corrected.

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APPENDIX C

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